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(54) TELEPHONE EXTENSION SYSTEM UTILIZING POWER LINE CARRIER SIGNALS

(71) We, WILLIAM M. BROWN, 25 Murphy Road, Hudson, Massachusetts, United States of America; JOHN M. RUDDY, 42 Pantry Road, Sudbury, Massachusetts, United States of America; and ROBERT T. DUNN, 4 Cedar Ridge Drive, Bedford, Massachusetts, United States of America, all citizens of the United States of America, do hereby declare the invention, for which we pray that a Patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to telephone extension systems providing a portable or mobile extension telephone which communicates over AC power wires. More particularly, the present invention provides apparatus for communicating over AC power wires between an extension telephone and a conventional telephone line.

According to the present invention, there is provided, a power line telephone extension system in a subscriber's premises wired with AC power wires, comprising a subscriber's telephone line entering the premises from a conventional telephone system, the subscribers line including a trip wire and ring wire, a master station coupled to the trip and ring wires and coupled to the power wires by a reactive coupling circuit, and an extension station coupled to an extension telephone and coupled to the power wires, at least one of the said stations being arranged to modulate telephone signals on to a carrier and to couple the modulated carrier into the power wires, and at least the other of the stations being arranged to detect and demodulate the modulated carrier to reconstitute the telephone signals.

The invention will be described in more detail, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a pictorial representation of an extension telephone system including two extension telephones which communicate with a conventional telephone line via available AC power wires and a conventional on line telephone which communicates with the same telephone line;

Figure 2 is an electrical block diagram showing the principal electrical circuits at the master station between the telephone line and the available AC power wires;

Figure 3 is an electrical block diagram showing the principal electrical circuits at one of the extension telephone stations which couple the extension telephone to the AC power wires for communication with the telephone line and the on line telephone;

Figure 4 is a detailed electrical block diagram of the master station transmit-receive unit;

Figure 5 is a diagram showing the sequence of cradle switch, transfer/hold and other signals that initiate coupling of the system to the subscriber's telephone line;

Figure 6 is a detailed electrical block diagram of the extension station transmit-receive unit; and

Figure 7 is a circuit diagram of a conventional battery telephone transmission network of the type used in many conventional telephone handsets and which is for example, the ITT type 75335-1 network, and is suitable for use in the master station transmit-receive unit.

The embodiment of the invention includes one or more extension telephones, each equipped with an extension transmit-receive unit (extension TR unit) enabling the extension phone to couple directly to the available AC power wires, and a master transmit-receive unit (master TR unit) at the master station which connects directly to the available AC power wires and also couples to the telephone line on which there is a conventional on line telephone. This system is illustrated pictorially in Figure 1. The master TR unit serves as an interface between the subscriber's line and the available AC power wires. These power wires act as a transmission medium for the signals on the telephone line and carry these signals to the extension telephone stations and also carry signals from the extension telephone stations to the telephone

line. Any number of extension telephones may be used in this system, each transmitting a different extension carrier frequency, and to initiate operation, it is only required that the extension TR unit of the extension telephone be plugged into the AC power wires. Thus, every AC power outlet connected to the power can be used as an extension telephone station. With this system in operation, all telephone line signals at the subscriber's telephone line are fed to the extension telephones which are plugged into the AC power wires. Furthermore, by virtue of the operation of the extension and master TR units, calls can be placed by the subscriber on the telephone line from any of the extension stations which are plugged in, and any extension station can communicate directly with the telephone line whether or not the subscriber's conventional telephone is connected to the line. In addition, extension stations which are plugged into the AC power wires can communicate with each other without any actuation or use of the subscriber's conventional on line telephone at the master station. Also, a call can be held by the extension telephone and the extension phone can be unplugged (disconnected from the system), moved and plugged in again to continue the call.

Turning to Figure 1, there is shown the subscriber's telephone line 1 and the subscriber's on line telephone 2 (herein called the master telephone). Both the telephone line and the master telephone are of conventional design and are usually provided by the local telephone company. For purposes of example, the telephone system described herein is a conventional system sometimes referred to as a common battery telephone system which provides a telephone line to each subscriber. The subscriber's telephone is on the line at all times and is energized by direct current over the telephone line from a central telephone switching system which may be a PBX, panel, step by step, crossbar or electronic switching system.

In a preferred embodiment of the present invention, both the telephone line 1 and the line 3 from the master telephone connect together through a master station connector 4. This connector is merely a feed through with respect to lines 1 and 3. In addition, the connector provides telephone line connection to the master station TR unit 5. This connection is line 6 and may be no different than the telephone line connection to a conventional telephone line extension phone. Hence, the connector 4 may be a conventional telephone extension receptacle.

The master station TR unit, connects directly to the available AC power wires 7. This connection is conveniently through a conventional AC power receptable 8 and includes a power cable 9 from the master unit with a conventional plug 10 at the end of this wire to accommodate the receptacle.

The master TR unit performs numerous functions. For example, it is a buffer between the telephone line 1 and the AC power wires 7 so that there is no direct mains frequency AC electrical connection between the telephone line wires and the power wires. In addition, the master unit imposes a conventional impedance load on the telephone line, via line 6 and the connector 4, so that the telephone line is at all times electrically loaded as required by the central switching system, whether or not the subscriber's master telephone 2 is on the line. The structure and other functions of the master TR unit are more fully described herein.

For purposes of example, two extension stations are shown in Figure 1, numbered I and II and both are plugged into the AC power wires via conventional power receptacles. Clearly, any number of extension stations can be added and any number can be on the power line at the same time. Since all the extension stations may be the same, except that they generate and transmit different extension carrier frequencies, only extension station number I is described herein in greater detail.

The extension station includes an extension TR unit 15 which couples the extension telephone 12 to the extension station AC power outlet 18. This connection is made by an AC power connecting line 19 from the extension unit with an AC plug 20 at the end of this cable which plugs into the receptacle 18. The extension TR unit 15 and the extension phone 12 are connected by lines 16. These lines, the extension unit and the extension phone are described herein in further detail.

The master and extension TR units 5 and 15 are similar in many respects. Each includes a carrier frequency generator and a carrier frequency receiver. Furthermore, the extension telephone 12 may be a conventional phone which couples to the extension TR unit via lines 16 that carry relatively low level voltage, voice, ring, dial, etc. signals between the extension phone and the telephone line to enable all uses of the extension telephone described herein and all uses which are normally available to a conventional extension telephone.

The extension telephone such as 12 in connection with the subscriber's telephone line as shown in Fig. 1 can be installed easily in any subscribing home or business location where ordinary AC power outlets are available. There is no limitation on the number of extension phones that can be employed on the AC power line at any one time. The only limitation might be the length of the AC power line and the number of loads that can be imposed on the line at any one time which

may absorb the carrier frequency signals transmitted between the extension and master stations. This problem can be partially overcome by employing relatively high carrier frequency power and selecting carrier frequencies which are readily detected at the master and extension stations even though they are very substantially attenuated in the AC power system. In addition, suitable filters at the master and extension TR units, are provided to screen out noise from the AC power system and enable clear detection of the carried signal even in the presence of a high level of noise.

Turning next to Figures 2 and 3, there are shown detailed block diagrams of the electrical circuits at the master and extension stations, and particularly the master and extension TR units and the interconnections between these units and the extension telephone. In Figure 2, the master unit includes a conventional transmission network 21. For purposes of example, this transmission network is identified as an ITT type 75335-1 transmission network sold by International Telephone and Telegraph Company and is shown in greater detail in Figure 7. The telephone line 1 connects directly to the input of network 21 through the connector 4 and telephone line 6. As already mentioned, lines 1, 3 and 6 may be a conventional telephone line. Two outputs of the network are denoted RING and MIC. The RING output is obtained from terminals G and L_2 (Fig. 7) of the network and carries the telephone ring signals from the telephone line. The MIC output is obtained from terminals R and B of the network of Fig. 7 and carries the voice signals from the telephone line. The RING output is fed to the ring detector circuits 22 and the MIC output is fed to the microphone circuits 23. The outputs of these circuits are amplified by variable gain audio amplifiers 24 and 25, respectively, and combined by algebraic summing circuit 26 and fed to the master carrier modulator transmitter 27. In this transmitter, the combined voice and ring signals modulate the master carrier frequency (also referred to herein as the first carrier frequency) and this modulated carrier is fed to diplexer unit 28, where it is filtered and applied to one side of RF coupling network 29 which connects to the AC power wires via power line 9 and plug 10. Thus, the ring and the voice signals on the telephone line, whether they come from a switching station or whether the voice signals come from the master telephone 2, are combined in the master TR unit 5 and modulate the master carrier frequency which is imposed on the available AC power wires at the master station for transmission to the extension station along the power wires.

The same AC power wires also bring signals from the extension station on the extension carrier frequency to the master unit. The signals from the extension station modulate the extension carrier frequency which feeds through plug 10 and power line 9 to the RF coupling network 29 which feeds diplexer unit 28. The diplexer separates the extension carrier from the master carrier frequency and feeds the modulated extension carrier frequency, via line 31, to the extension carrier frequency receiver and demodulator 32.

The signals from the extension station include voice signals, dial signals, extension cradle switch signals and hold/transfer signals. These all appear in the output of demodulator 32. The voice signals are amplified by a band pass audio amplifier 33 which is limited to the band pass of the telephone line system (typically 300 to 3300 Hz). The output of audio amplifier 33 is coupled to the earphone terminals EAP of the transmission network via the earphone coupling circuit 34.

The output of demodulator 32 is also fed to amplifier 35 which has a somewhat wider band that includes the band of amplifier 33, for amplifying cradle switch signals, dial signals and transfer/hold signals from the extension station. The output of amplifier 35 is applied to the DIAL Terminals of the transmission network via the dial pulse circuits 36. Where the dial signals from the extension station are pulses (sometimes called dial clicks) as produced by a conventional rotary telephone dial, these dial pulse circuits may consist of a solenoid driving a normally closed switch, the switch being connected to the F and RR terminals of the transmission network, shown in Fig. 7, and the solenoid being driven by the output of amplifier 35. The master unit of this construction and function is shown in greater detail in Figure 4.

The transfer/hold signals and the cradle switch signal in the output of demodulator 32 are amplified by amplifier 35 and fed to the transfer/hold and cradle switch circuits 37 and 38, respectively. These signals may be combined in the cradle switch circuits and applied to the CRSW terminals in the tip and ring lines of the transmission network shown in Fig. 7. Thus, dialing signals, cradle switch signals and transfer/hold signals originating at the extension telephone are carried to the master unit on the extension carrier frequency over the AC power wires and are received, demodulated and applied to the appropriate terminals of the transmission network. Furthermore, since the transmission network is coupled by line 6 to the subscriber's telephone line 1, the same signals are carried to the telephone line and accomplish the same functions there as would be accomplished by the same kind of signals from a conventional extension telephone con-

nected directly to the subscriber's telephone line.

The extension station TR unit 15 and extension telephone 12 are shown in Figure 3 with the major circuits thereof in blocks. The master carrier frequency in the AC power line is fed to the extension coupling network 41 via plug 20 and Ac power line 19. From the coupling network 41 the master frequency is fed to the diplexer unit 42 where it is separated from the extension frequency and fed on line 43 to the master carrier frequency receiver and demodulator 44. Thus, the output of the demodulator 44 consists of voice signals equivalent to the voice signals on the subscriber's telephone line 1 and ring signals representative of the ring signals on the subscriber's telephone line 1. These voice signals are amplified by amplifier 45 and applied to the earphone circuits 46 which energize the earphone 47 of extension telephone 12 through one of the lines 16.

Similarly, the ring signal in the output of demodulator 44 is amplified by amplifier 48 and fed to ring detector circuits 49 which control energization of the extension telephone bell or buzzer 51. This bell may be located within the extension TR unit 15 or it may be located in a conventional manner in the extension telephone 12.

The signals which originate at the extension telephone 12 include the extension cradle switch signal from the extension cradle switch 52, the extension dial signals from the extension dial 53, the extension voice signals from the extension microphone or mouthpiece 54 and the extension transfer/hold signal from the transfer/hold switch 55 of the extension telephone. These signals are fed to correspondingly named circuits 62 to 65 in the extension TR unit. The outputs of circuits 62, 63 and 65 are amplified by amplifier 66, 67 and 69, respectively, and the outputs of these are combined by summing circuit 71 and amplified by variable gain amplifier 72. The voice signals from extension microphone 54 are amplified by microphone circuits 64 and fed to variable gain voice band amplifier 68.

Amplifiers 68 and 72 are preferably variable gain amplifiers so that the gains thereof can be adjusted in view of the attenuation of the extension phone carrier frequency in the AC power line between the extension station and master station. These outputs of amplifiers 68 and 72 are combined by summing circuit 73 and fed to extension carrier frequency modulator and transmitter 74. The output of transmitter 74 carrying modulated extension carrier frequency is fed to diplexer unit 42 wherein it is separated from the master carrier frequency and then fed to the coupling network 41 for coupling to the AC power wires via power line 19 and plug 20.

Additional details of the master TR unit 5 including a few slight variations of the system shown generally in Figure 2 are shown in Figure 4. The circuits and components shown in Figure 4 which are or may be the same as the circuit blocks shown in Figure 2 which make up the master unit, bear the same reference numbers. Figure 4 does not show the transmission network 21, but rather shows in detail the terminals of the conventional transmission network of Fig. 7 as it may be used in the master unit. This particular transmission network is identified as the ITT type 75335-1 which is part of a great many conventional telephone hand sets in current use.

The outputs of transmission network 21 shown in Figure 4 are the RING terminals and the MIC terminals. The RING terminals are terminals G and L_2 to which the ring detector circuits 22 in the master unit are connected. These ring detector circuits include a full wave rectifier diode bridge circuit 81 to which the terminals G and L_2 of the transmission network are coupled via capacitors denoted Cr. The output of this bridge is connected to the input of the ring signal threshold detector 82 which includes a smoothing filter and the output of this detector is applied across the coil 84 of a normally opened solenoid relay with contacts 85. When these contacts close, they connect the output 83 of the 1,000 Hz tone oscillator 86 to the input of variable gain amplifier 25. This amplifier preferably operates over a 10% band centered at a convenient ring tone frequency such as 1,000 Hz. The gain of this amplifier is controlled by variable potentiometer 25′.

The MIC terminals of the transmission network, denoted R and B connect across the primary coil of transformer 87 which is the equivalent of the microphone circuit 23 shown in Figure 2. The secondary of this transformer connects to the input of variable gain amplifier 24 which preferably operates over the voice frequency range 300 to 3300 Hz. The gain of this amplifier is controlled by variable potentiometer 24′.

The outputs of amplifiers 24 and 25 are fed to algebraic summing circuits 26 which combine the ring tone signal of 1,000 Hz and the voice signals which lie in the band 300 to 3300 Hz and these combined signals are fed to the master carrier frequency modulator and transmitter 27. This modulator consists of a variable frequency oscillator 88 which is centered at a frequency substantially higher than the telephone line frequencies and higher than frequencies normally appearing in the AC power wires. For example, this frequency may be 240 QKHz. The output of this oscillator is amplified by class A power amplifier 89 and fed to the high pass filter 90 in diplexer unit 28. This high pass filter has a 3 db cut off frequency of 200 KHz. Thus,

the output of high pass filter 90 in the master RF or master carrier frequency which is frequency modulated by the voice and ring tone signals derived from the subscriber's telephone line 1. This modulated master carrier frequency is coupled to the AC power line by the RF coupling network 29 which may consist of an RF transformer 91 which couples to the AC line 9 by capacitors C_c, denoted 92.

The RF coupling network 29 functions in to the AC power line and couples the extencarrier frequency from the transmitter 27 to the AC power line and couples the extension carrier frequency from the AC power line to the low pass filter 93 in the diplexer unit 28. In the direction from the master carrier transmitter 27 to the AC power line, the primary coil 94 of RF transformer 91 includes a centre tap to ground and the capacitances 92 connect the secondary coil 95 of this transformer to the AC power wires.

The extension carrier frequency, like the master carrier frequency, is far higher than the normal operating band of the telephone line and is higher than frequencies normally appearing in any significant amplitude in the AC power wires. However, the extension carrier frequency differs sufficiently from the master carrier frequency so that they can be discriminated readily one from the other. For example, if the master frequency is centered at 240 KHz, then the extension carrier frequency is conveniently centered at 90 KHz. Accordingly, the 3 db cut off frequency of low pass filter 93 is 100 KHz. The output of this filter (which is extension carrier frequency modulated by the various signals generated at the extension telephone), is fed to the extension carrier frequency receiver and demodulator 32. The receiver portion of this consists of a variable gain amplifier 101 and an FM demodulator circuit 102. The gain of amplifier 101 is controlled by variable potentiometer 101'.

The output of demodulator 102 consists of the various signals generated at the extension telephone. These include the voice signals in the frequency range 300 to 3300 Hz and separate narrow band tones, one carrying the extension cradle switch signal, another the dial pulse signals and, a third the transfer/hold signal. The generation of these separate narrow band tones to carry each of these different signals is explained more fully herein with respect to Figure 6 which shows the extension TR unit 15 wherein these tones are generated. For example, the cradle switch signal may be carried by a narrow band tone centered at 100 Hz, the dial pulse signals may be carried by a narrow band tone centered at 3000 Hz and the transfer/hold signals may be carried by a narrow band tone centered at 2,000 Hz. These tones are separated in the output of amplifier 35 by varible gain amplifiers 103, 104 and 105 which operate over the narrow bands centered at 100 Hz, 3,000 Hz and 2,000 Hz, respectively, and so the outputs of these amplifiers are limited to the cradle switch signal, the dial pulse signals and the transfer/hold signal, respectively and each is represented by a different tone. These tones are decoded by detecting the envelopes of these tones which represent the associated signals. For this purpose, detectors 106, 107 and 108 are provided which produce in the output thereof the cradle switch, transfer/hold and dial pulse signals, respectively.

The transfer/hold signal in the output of decoder 108 is fed to the flop input of flip-flop circuit 110. This flip-flop circuit is a double input, bistable multivibrator of conventional construction and is triggered by a sharply rising voltage level (a spike pulse) at either input. For purposes of example, the flip stage is the "zero" state and the flop is the "one" state of this multivibrator and the output is from the flop or one state. This output is a zero or one voltage level and is fed along with the "zero" or "one" voltage level in the output of the cradle switch decoder 106 to OR gate 112 which energizes the solenoid 113 of normally open, switch relay 114.

The two switches 115 and 116 of relay 114 connect to the cradle switch CRSW terminals of the transmission network 21 in the tip and ring lines thereof. These terminals, shown in Fig. 7, are L_1 and F which connect to switch 115 and L_2 and C which connect to switch 116. Hence, a "one" signal level in the output from flip-flop 110 or cradle switch tone decoder 106 closes switches 115 and 116 and makes the master unit 15 responsive to signals on the subscriber's telephone line 1.

The flip or "zero" stage of flip-flop 110 responds to spike pulses from initialization circuit 111. These spike pulses are derived either from the power supply voltage V_1 from the DC power supply 30 when the master TR unit 15 is turned on (such as when it is plugged into the AC power line), or from the initiation of a "one" signal level in the output of cradle switch tone decoder 106. Thus, following turn on the master TR unit or lifting the extension telephone bandset from its cradle, the flip-flop is set to its "zero" state.

Typical operation of the relay 114 to control coupling of the tip and ring lines of network 21 to the subscriber's telephone line, is illustrated by the diagrams of Fig. 5. This shows the types of signals produced by decoders 106 and 108 and by circuit 111, and the states of flip-flop 110 and the tip and ring line connections to the telephone line at a number of typical operating events. For example:

At t_1—the master station is turned on producing power supply voltage V_1 which causes a spike output pulse

from circuit 111 that sets the flip-flop 110 t the "zero" state.

At t_2—the extension handset is lifted from its cradle.

At t_3—the extension transfer/hold button is momentarily depressed.

At t_4—the extension handset is returned to its cradle.

At t_5—the extension TR unit is unplugged from the AC power line—(and is moved)

At t_6—the extension TR unit is plugged into the AC power line.

At t_7—the extension handset is lifted from its cradle.

At t_8—the extension handset is returned to its cradle.

This sequence of events shows that the master unit transmission network 21 is coupled to the subscriber's telephone line upon answering the extension phone and remains coupled after the transfer/hold button is actuated even when the extension is unplugged from the system, moved and then plugged in again.

The dial pulse circuits 36 in the master unit in Figure 4 consist of variable gain amplifier 104 amplifying the signals from amplifier 35 and the dial pulse decoder (envelope detector) 107. The amplifier 104 operates over a narrow band centered at the 3,000 Hz dial pulse tone and selectively amplifies only the dial pulse tones appearing in the output of amplifier 35. The decoded dial pulse tone, consisting of dial pulses, appears in the output of this decoder and is applied to the solenoid 121 of relay switch 123. The switch 123 in this relay is normally closed and so each dial pulse causes the switch 123 to momentarily open. Since this switch connects to the DIAL terminals F and RR of the transmission network 21, the dial pulses are applied to the network and from the network to the subscriber's telephone line 1 via the master connector 4. Thus, all signals originating at the extension telephone are carried to the master TR unit over the AC power wires and decoded to suitable form for coupling to the conventional telephone line transmission network that connects to the subscriber's telephone line. In this manner, the extension telephone is made as effective as a conventional telephone on a conventional extension of the subscriber's telephone line. More particularly, the extension telephone described is capable of answering and receiving incoming telephone calls and conducting conversations with the incoming call. It can place a call on the telephone line and initiate a hold position so that the same call can be answered also on the master telephone or on another extension telephone or so that the extension phone answering the call can be unplugged, moved and plugged in again to continue the call. Furthermore, all these functions can be performed with or without the master telephone on the telephone line and no action has to be taken with regard to the master telephone in order to perform these functions.

Additional details of the extension station TR unit 15 are shown in the block diagram, electrical schematic of Figure 6. As shown in this figure, the master carrier frequency is coupled from the AC power line through the RF coupling network 41 which may consist of two capacitances 131 connected to the primary 132 of an RF transformer 133 in the direction of incoming master carrier frequency. The secondary 134 of this transformer, in the same direction, includes a centre tap to ground. The master carrier frequency from this transformer feeds through high pass filter 135 cut-off at 200 KHz to the master carrier frequency receiver and demodulator 44. This receiver and demodulator consists of a variable gain amplifier 136, a low pass broadcast filter 137 and FM demodulator 138. The variable gain amplifier 136 has a narrow frequency band of operation centered at about 240 KHz.

Since the signals that modulate the master carrier frequency consist of the 1,000 Hz ring tone generated by the tone oscillator 86 in the master unit, and the voice signals from the MIC terminals of the transmission network in the master unit, the output of FM demodulator 138 consists of these same voice signals and the 1,000 Hz ring tone signal. The voice signals in this output are amplified by variable gain amplifier 45 which energizes the earphone circuit 46 that in turn, energize the earphone 47 of the extension telephone. The circuit 46 may include, for example, a capacitance 139 in series with inductance 140.

The ring tone signal in the output of demodulator 138 is amplified by variable gain amplifier 48 which drives the ring and tone decoder (ring tone envelope detector) 141 that energizes the coil 143 of relay switch 142. The switch 144 of relay 142 is normally open and closes when the ring signal is present in the output of the decoder. When this switch closes, it turns on the buzzer or bell 51.

The extension telephone signals, excluding the voice signals from the microphone 54, are each converted to a representative tone so that each can be distinguished from the other at the master unit by the distinguishing tone. In the extension unit, these tones modulate the extension carrier frequency which is then transmitted over the AC power wires to the master unit. These identifying tones are preferably single frequencies, all within the voice frequency band width. That is, they fall within the 30 to 3300 Hz band. Furthermore, these tones are selected in view of the signal which they are to convey and are

separated substantially from each other to ensure there is no overlap. With this in mind, it is convenient if the cradle switch signal is carried by a tone at about 100 Hz and the dial pulses are carried by a tone at the other end of the available band, such as 3,000 Hz. This leaves the transfer/hold signal from the extension telephone to be carried by a tone between the other two or about 2,000 Hz. Thus, the cradle switch, dial and transfer/hold circuits 62, 63 and 65 shown in Figure 3 may each be an oscillator which is turned on whenever the associated signal is present. For example, the cradle switch circuit 62 may be a 100 Hz oscillator which is turned on whenever the cradle switch opens. The dial circuit 63 is a 3,000 Hz oscillator which is turned on at each dial pulse or click and the transfer/hold circuit 65 is a 2,000 Hz oscillator turned on each time the transfer/hold switch is actuated. These oscillators feed amplifiers 66, 67 and 69, respectively and the outputs of these amplifiers are combined by algebraic summing circuit 71.

The voice signals from the extension phone microphone 54 are fed to the microphone circuit 64 which may consist of an input inductive impedance 151 and amplifier 152. The band of operation of this amplifier is preferably at least from 300 to 3300 Hz which is in the voice frequency range.

Variable gain amplifiers 72 and 68 feed the tone signals and the voice signals to algebraic summing circuit 73 which in turn, controls the variable frequency oscillator 153 in the extension carrier frequency modulator and transmitter 74. Oscillator 153 has a centre frequency of about 90 KHz and so the upper sideband output of this oscillator is in the range of 90 to 100 KHz. This sideband is amplified by class A power amplifier 154 and fed through low pass filter 155 in the diplexer unit 42. This low pass filter has a cut off frequency of 100 KHz and so it passes the extension carrier sideband to the RF coupler 41 that feeds the sideband to the AC power wires via the AC plug 20.

The variable gain amplifiers 72 and 68 each have a control potentiometer 72′ and 68′, respectively, for controlling the gain. These potentiometers may be preset or they may be varied at installation or even during use as necessary to control the amplitude of the tone and voice signals that modulate the extension carrier frequency. Variable gain amplifiers 45 and 48 also include variable potentiometers 45′ and 48′, respectively, for the same purpose.

A typical ITT type 75335-1 transmission network 21 is shown in detail in Figure 7. This network connects directly to the subscriber's telephone line as shown, the telephone line being represented by the tip and ring wires 161 and 162 and ground wire 163. The first set of terminals, which are across the lines 162 and 163 are the RING terminals consisting of G, A, K and L_2. Of these, G connects to 163, and L_2 connects to 162 and G and L_2 connect also to the ring tone detector circuit 22 in the master unit. The CRSW terminals L_1 and F in the tip line side 165 of the network connect to the normally open switch 115 of relay 114, Fig. 4. Similarly, the CRSW terminals L_2 and C in the ring line side 166 of the network connect to switch 116 in the same relay. Thus, when this relay is energized by the cradle switch signal or the transfer/hold signal, terminals L_1 and F on the tip side and terminals L_2 and C on the ring side of the network are short circuited.

The dial pulse or dial click signals appearing in the output decoder 107 in the master unit cause normally closed switch 123 of relay 122 to open then close with each pulse. The terminals of this switch connect to the DIAL terminals in tip line side of the transmission network and so these dial pulses are produced in the telephone line when these terminals are opened and closed by the switch 123.

A radio frequency filter 170, also called an equalizer circuit across the tip and ring sides of the network includes a varistor 167 in series with the combination of resistor 168 and capacitor 169. The capacitor here suppresses dial pulse transients to prevent them from causing radio interference and the resistor and the varistor form the line equalizer that acts as a shunt on short loops to limit the power transmitted by the transmission network to the telephone line and vice versa. If this power level is too high, cross talk problems occur.

The induction coil TA_1—TC in the tip line side and the induction coil TA_2—TB in the ring line side of the network are each split to balance the impedance on each side of the line. These inductances are split on each side of the MIC terminals R and B to which the microphone transformer 87 connects, as shown in Fig. 4 and imposes a load equivalent to the carbon microphone of a conventional telephone. This transformer 87 and the resistor 171 make up the network transmitter impedance of what is sometimes called the anti-sidetone circuit. The capacitors 172 and 173 and resistor 174 make up the anti-sidetone balancing impedance. Varistor 175 compensates for changes in line impedance so that desired conditions are maintained to control sidetone levels.

The earphone circuit 34 connects to the earphone terminals GN and R of the transmission network. This circuit consists of the transformer 34 at the output of variable gain amplifier 33 that amplifies voice signals derived from the extension telephone. This transformer provides an impedance equivalent to the impedance of a conventional tele-

phone earphone, and that impedance makes up the receiver leg of the transmission network. Varistor 175 limits the output level of the receiver leg to levels well below those which might be objectionable to the user.

Thus, the transmission network can be the same as the transmission network in a conventional telephone and all the input and output terminals of that network are provided with impedances which are equivalent to those that are connected to such a network as in a conventional telephone. As a result, the signal levels and impedances imposed on the subscriber's telephone line are in all respects conventional and not particularly distinguishable from the signal levels and impedances that would be imposed by a single master telephone of conventional design connected directly to the telephone line.

WHAT WE CLAIM IS:—

1. A power line telephone extension system in a subscriber's premises wired with AC power wires, comprising a subscriber's telephone line entering the premises from a conventional telephone system, the subscriber's line including a trip wire and ring wire a master station coupled to the trip and ring wires and coupled to the power wires by a reactive coupling circuit, and an extension station coupled to an extension telephone and coupled to the power wires, at least one of the said stations being arranged to modulate telephone signals on to a carrier and to couple the modulated carrier into the power wires, and at least the other of the stations being arranged to detect and demodulate the modulated carrier to reconstitute the telephone signals.

2. A system according to claim 1, wherein to modulate signals on the subscriber's line the master and extension stations are equipped and from the extension telephone respectively on to respective master and extension carriers for coupling on to the power wires, and are equipped to detect modulated carriers from the power wires to provide telephone signals respectively to the subscribers line and the extension telephone.

3. A system according to claim 2, wherein the signals from the subscriber's line include the ring signal and voice signals, the ring signal causes the extension telephone to ring and when the extension telephone is answered, signals equivalent to the voice signals present on the telephone line energize the earphone of the extension telephone.

4. A system according to claim 2 or 3, wherein the master station includes a conventional telephone transmission network which imposes a load impedance on the subscriber's line compatible with the telephone system, the signals carried on the subscribers line are coupled from the transmission network to a master carrier frequency modulator wherein the telephone signals modulate th master carrier frequency, and this modulated master carrier frequency is coupled to the power wires at the master location by the reactive coupling circuit.

5. A system according to claim 4, wherein the signals from the subscribers line are the ring signal and voice signals and these signals are combined and fed to the master carrier frequency modulator.

6. A system according to claim 5, wherein the extension telephone includes a bell, a handset carrying an earphone and a handset cradle switch, the ring signal and the voice signals which are combined and modulate the master carrier frequency and are coupled to the power wires, are coupled from the power wires at the extension location on the power line and are fed to a master carrier frequency demodulator which produces ring and voice signals, means are provided for detecting the ring signal from the output of the master carrier frequency demodulator, means are provided for energizing the extension telephone bell in response to the detected ring signal, and means are provided for energizing the extension telephone earphone in response to the voice signals in the output of the master carrier frequency demodulator.

7. A system according to claim 6, wherein means are provided whereby the bell is energized in response to the ring signal in the output of the master carrier frequency demodulator when the cradle switch is actuated by the handset, and means are provided whereby the earphone is energized by the voice signals in the output of the master carrier frequency demodulator when the cradle switch is not actuated by the handset.

8. A system according to claim 7, wherein the telephone transmission network, the means for combining the ring signal and voice signals, the master carrier frequency modulator, and the reactive coupling circuit are contained in a unitary package at the master location, and the extension receiver means, the means for coupling master carrier signals thereto, the master carrier frequency demodulator, the means for energizing the extension telephone earphone are contained in a unitary package at the extension location.

9. A system according to claim 4, wherein means are provided at the master location for detecting the ring signal from the transmission network and initiating a ring tone signal in response thereto, means are provided at the master location for combining the ring tone signal and the voice signals from the transmission network, the master carrier frequency modulator responds to said combined signals, producing in the output thereof of said master carrier frequency, modulated by ring or voice signals, and means are provided at the extension location responsive to the master carrier frequency demodulator for

detecting said ring tone signals, and the output thereof initiates energization of the extension telephone bell.

10. A system as in claim 9, wherein the frequency of the ring tone lies within the frequency of the voice signal frequency band, the ring tone detector is tuned narrowly to the tone frequency, and the threshold of the ring tone detector is sufficiently high to exclude any portion of the voice signals from initiating energization of the extension telephone bell.

11. A system according to any of claims 4 to 10, wherein the master carrier modulation by the signals carried on the subscriber's line is frequency modulation, and the master carrier frequency centre frequency is substantially higher than the telephone line operating frequency band.

12. A system according to any of claims 2 to 11, wherein the master and extension carrier frequencies are substantially different and both are substantially higher than the frequency band of operation of the subscriber's line.

13. A system according to any of claims 2 to 12, wherein the extension station comprises means for generating an extension telephone cradle switch signal, and means for modulating the extension carrier frequency by the cradle switch signal as also the extension dial and voice signals modulate the extension carrier frequency, whereby the modulated extension carrier signals include dial signals, voice signals and the cradle switch signal; and at the master station, the extension cradle switch signal is reproduced and means are provided for coupling the cradle switch signal to the electrical circuits coupled directly to the subscribers line for controlling the coupling thereof.

14. A system according to claim 13, wherein the extension station comprises means for generating an extension telephone transfer/hold signal and means for modulating the extension carrier frequency by the transfer/hold signal as also the extension dial, voice and cradle switch signals modulate the extension carrier frequency, whereby the modulated extension carrier signals include the cradle switch, dial, voice and transfer/hold signals; and a master location, the extension transfer/hold signal is reproduced and means are provided for coupling directly to the subscriber's line for controlling the coupling thereof.

15. A system according to claim 14, wherein the master station comprises means whereby the reproduced cradle switch and transfer/hold signals cause the electrical circuits to couple directly to the telephone line when.

1. the cradle switch signal is present
2. following the simultaneous occurrence of the cradle switch signal and the transfer/hold signal, the cradle switch signal ceases and said coupling to the subscribers line continues until the cradle switch signal commences again and then ceases again.

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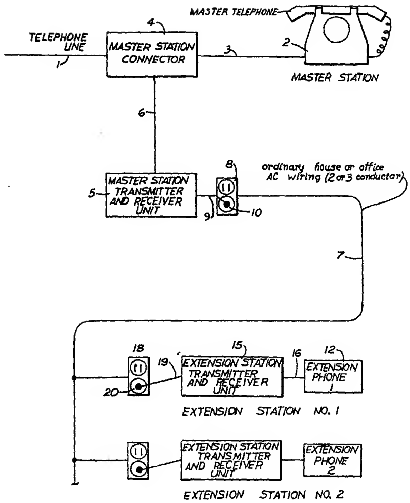
MASTER TELEPHONE
TELEPHONE LINE
1
4
MASTER STATION CONNECTOR
3
2
MASTER STATION
6
8
ordinary house or office AC wiring (2 or 3 conductor)
5
MASTER STATION TRANSMITTER AND RECEIVER UNIT
9
10
7
18
15
16
12
19
EXTENSION STATION TRANSMITTER AND RECEIVER UNIT
EXTENSION PHONE 1
20
EXTENSION STATION NO. 1
EXTENSION STATION TRANSMITTER AND RECEIVER UNIT
EXTENSION PHONE 2
EXTENSION STATION NO. 2

FIGURE 1

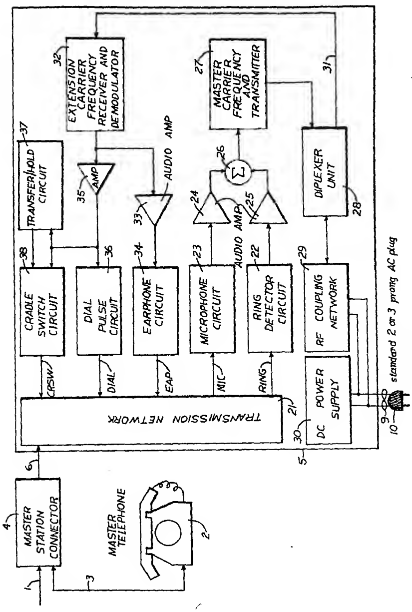
MASTER STATION CONNECTOR
MASTER TELEPHONE
TRANSMISSION NETWORK
CRSW
DIAL
EAP
MIC
RING
CRADLE SWITCH CIRCUIT
DIAL PULSE CIRCUIT
EARPHONE CIRCUIT
MICROPHONE CIRCUIT
RING DETECTOR CIRCUIT
RF COUPLING NETWORK
DC POWER SUPPLY
TRANSFER/HOLD CIRCUIT
AMP
AUDIO AMP
AUDIO AMP
EXTENSION CARRIER FREQUENCY RECEIVER AND DEMODULATOR
MASTER CARRIER FREQUENCY AND TRANSMITTER
DIPLEXER UNIT
standard 2 or 3 prong AC plug
1
2
3
4
5
6
9
10
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38

FIGURE 2.

1548652 COMPLETE SPECIFICATION

7 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 3

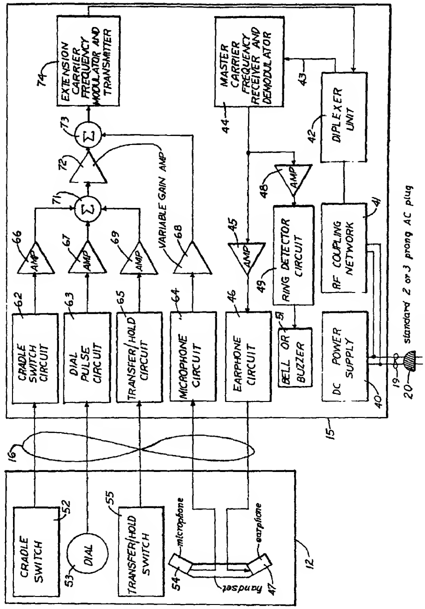

FIGURE 3.

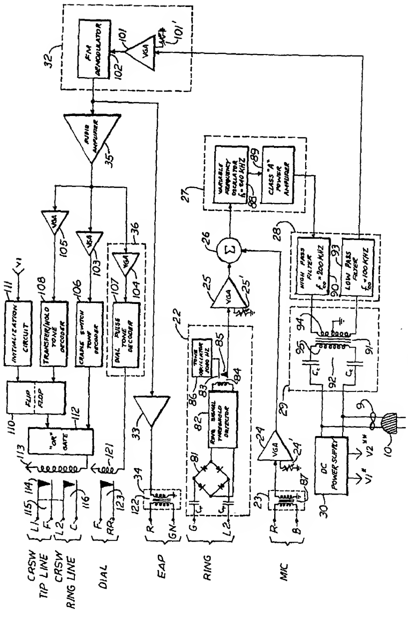

FIGURE 4.

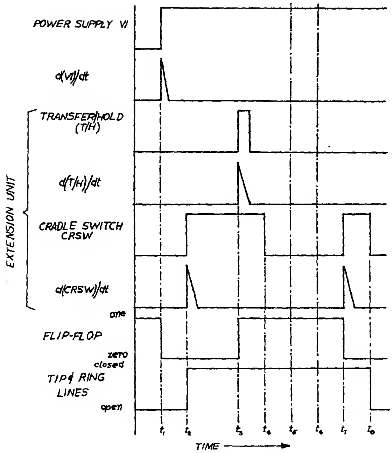
POWER SUPPLY VI
d(VI)/dt
TRANSFER/HOLD (T/H)
d(T/H)/dt
EXTENSION UNIT
CRADLE SWITCH CRSW
d(CRSW)/dt
one
FLIP-FLOP
zero
closed
TIP & RING LINES
open
t_1 t_2 t_3 t_4 t_5 t_6 t_7 t_8
TIME

FIGURE. 5

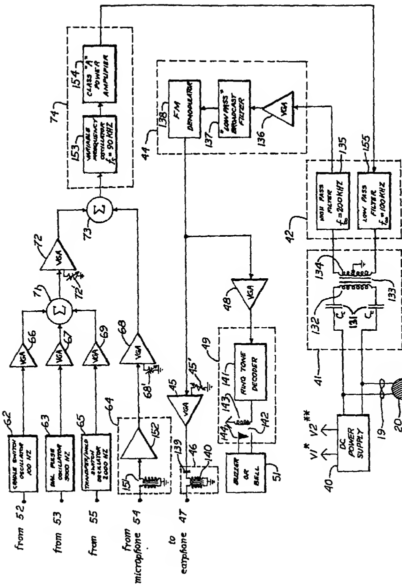
from 52
from 53
from 55
from microphone 54
to earphone 47
CRADLE SWITCH OSCILLATOR 100 HZ
DIAL PULSE OSCILLATOR 3000 HZ
TRANSFER/HOLD SWITCH OSCILLATOR 2000 HZ
VGA
Σ
VARIABLE FREQUENCY OSCILLATOR f_c = 90 KHZ
CLASS "A" POWER AMPLIFIER
FM DEMODULATOR
"LOW PASS" BROADCAST FILTER
RING TONE DECODER
BUZZER OR BELL
HIGH PASS FILTER f_{co}=200KHZ
LOW PASS FILTER f_{co}=100KHZ
DC POWER SUPPLY
V1*
V2**

FIGURE 6.

1548652 COMPLETE SPECIFICATION

7 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 7

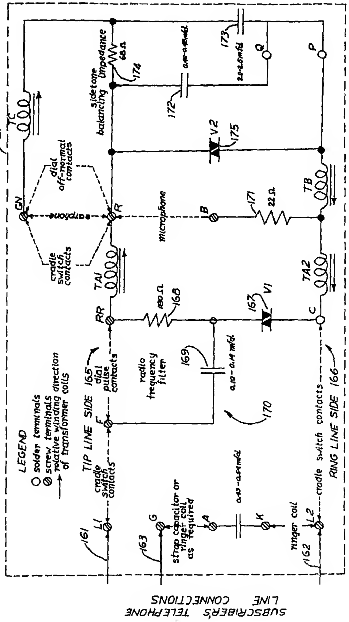

FIGURE 7.